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Fragmentation Functions approach in pQCD fragmentation phenomena

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Abstract

Next-to-leading order parton fragmentation functions into light mesons are presented. They have been extracted from real and simulated e^+e^- data and used to predict inclusive single particle distributions at different machines.

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1 Introduction

One of the fundamental properties of QCD is the shrinking of the coupling constant as the energy of the interactions grows (asymptotic freedom). This implies that perturbative techniques can be used to study high energy hadronic or leptonic phenomena. In spite of this, we can not rely completely on perturbation theory because the fundamental particles whose interactions become weak at high energy are deeply bound inside the hadrons we use as beams, targets or as observables. The solution is given by the factorization theorems, whereby cross sections can be expressed as the products of factors, each one involving phenomena appearing at different energy scales. A generic hadronic collisions with production of one hadron inclusive can be expressed as the convolution of the partonic hard cross section and structure and fragmentation functions, which represent respectively the parton density inside the hadrons and the hadron density inside the parton. Those parton model distributions acquire a scale dependence when the QCD corrections are included, the scale being the point where collinear initial (final) state divergencies are subtracted. Moreover these distribution are indipendent of the specific reaction. The universality of these distributions is a key property, since they are not calculated from first principles as they contain non-perturbative information. Nevertheless they evolve with the scale following Alterelli-Parisi type equations and this permits to extract them from a low-energy process and use them to predict rates for another one.

In this talk I'll concentrate on some recent sets of parton fragmentation functions into light mesons. These sets have been extracted from real and simulated e^+e^- data in a full NLO formalism. They have been used to predict inclusive single particle differential distributions at different energies and machine and to study jet fragmentation properties. The outline of the talk is the following: I'll describe briefly how the sets have been derived, then I'll give some results on the inclusive single particle predictions comparing with data when they are available.

2 Fragmentation functions from e^+e^- data

Parton fragmentation functions are defined as the density probability to find a hadron h inside a parton p. They are parametrized in the following form:

$$D_p^h(x, M_f) = N x^\alpha (1-x)^\beta \tag{1}$$

where x is the fraction of parton momentum carried by the hadron, while M_f is the scale the function is evaluated. They satisfied multiplicity, charge and momentum conservation sum rules and evolve following Altarelli Parisi type equation. This means that given a certain set of input functions at the scale M_{f0}^2 we can obtain the functions at any desired scale simply solving the AP equation. To obtain the input sets we need to rely on experimental informations, because FF are not calculable from first principle, owing the fact that they contain non-perturbative informations[1].

To extract the FF we use e^+e^- data. In the language of the QCD-improved parton model, in fact, the x distribution of the process $e^+e^- \to h + X$ emerges from the x distribution $(d\sigma/dx)(x, \mu^2, s)$ of $e^+e^- \to a + X$ through convolution with $D_a^h(x, M_f^2)$:

$$\frac{1}{\sigma_{TOT}} \frac{d\sigma(e^+e^- \to h + X)}{dx} = \sum_a \int_x^1 \frac{dz}{z} D_a^h(z, M_f^2) \frac{1}{\sigma_T OT} \frac{d\sigma_a}{dy} \left(\frac{x}{z}, \mu^2, M_f^2\right); \tag{2}$$

where $\sigma_{TOT} = N_c \sum_{i=1}^{N_f} e_q^2 \sigma_0$ and

[1] we can actually calculate in a completely indipendent way only heavy quarks fragmentation functions, because in this case the mass of the heavy object act as a natural cutoff.

$$\frac{1}{\sigma_{TOT}}\frac{d\sigma_{q_i}}{dy}\left(y,\mu^2,M_f^2\right)=e_q^2 N_c\frac{\sigma_0}{\sigma_{TOT}}\left\{\delta(1-y)+\frac{\alpha_s(\mu^2)}{2\pi}\left[P_{qq}^0(y)\ln\left(\frac{s}{M_f^2}\right)+K_q^T(y)+K_q^L(y)\right]\right\} \tag{3}$$

and

$$\frac{1}{\sigma_{TOT}}\frac{d\sigma_g}{dy}\left(y,\mu^2,M_f^2\right)=\frac{2\alpha_s(\mu^2)}{2\pi}\left[P_{qg}^{(0,T)}(y)\ln\left(\frac{s}{M_f^2}\right)+K_g^T(y)+K_g^L(y)\right] \tag{4}$$

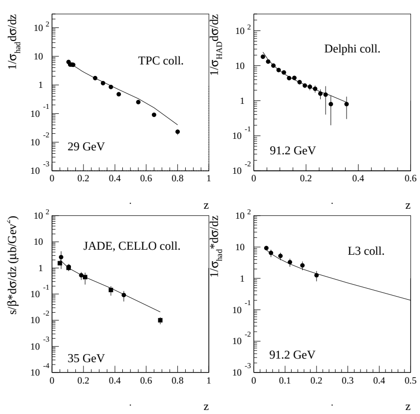

Figure 1: $K^{\pm}$ (upper right), K_s^0 (upper left) and η (lower) production using sets from ref.[6,8]

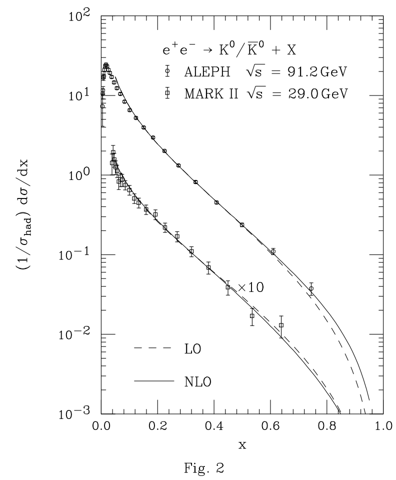

Figure 2: neutral kaons production at e^+e^- using the sets from ref.[5]

The functions K_q^T, K_q^L, K_g^T and K_g^L are shown in reference [1] and represent the NLO corrections. Using real and simulated[2] data several different sets have been derived for neutral[1] and charged pions[3, 4], neutral and charged kaons[6, 5] and η mesons[8] at different reference scales. In Figure 1 and 2 we give some examples on how well the different sets, when convoluted with the partonic cross sections, agree with e^+e^- data. We refer the readers to the previous references for further details.

3 Applications

As already stated, fragmentation functions are process independent: this means that we can use them to make predictions for process different from the one we used to extract them. We simply need to convolute them with the appropriate partonic cross sections. In the previous references the different sets have been used to give predictions on inclusive single particle production in hadron-hadron, hadron-lepton and photon-photon[9] collisions, and to phenomenologically describe jet fragmentation properties. In Figures 3, 4 and 5 we show again some examples on the NLO predictions for different energy ranges and process types.

Finally, in order to disentangle the fragmentation properties and the hadronization mechanism of high p_t jets, we consider the ratio between the single hadron and jet cross sections, for fixed values of the variable $z = E_{hadr}/E_{jet}$. Then, using the cone jet algorithm and the NLO evaluation of the jet cross sections of ref. [10], we present in Figure 6 a result on jet fragmentation in charged and neutral pions, with the energy of the jet varying between 40

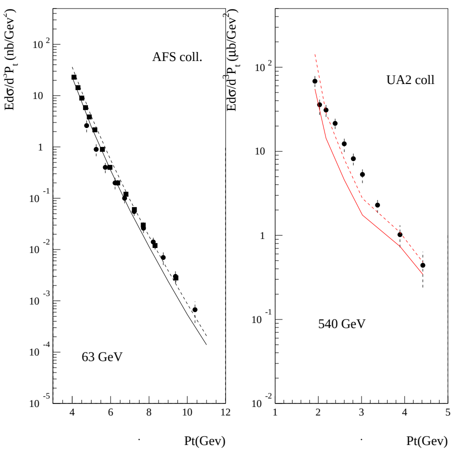

Figure 3: π^0 production at ISR and SppS using sets from ref.[1]

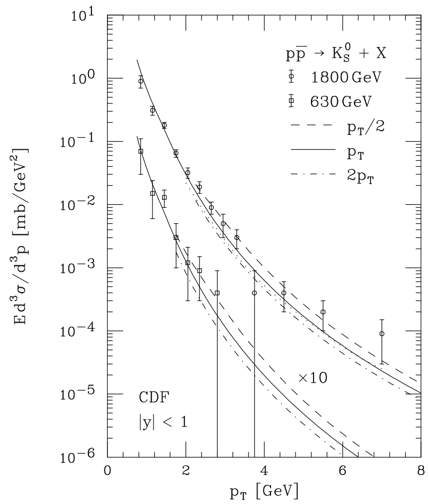

Fig. 5

Figure 4: K_s^0 production at TeVatron using sets form ref.[5]. The dotted line is from ref.[6]

and 70 GeV, and a jet cone radius R=0.7 centered around the $\eta = 0$ direction. The overall theoretical uncertainty -which is not reported in figure- can be estimated to be of order 50%. We also show the analogous experimental result on jet fragmentation in charged hadrons from CDF, in reasonable agreement with the theoretical prediction.

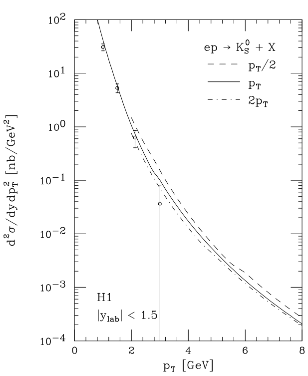

Fig. 3

Figure 5: K_s^0 production at HERA, using sets from ref.[5]

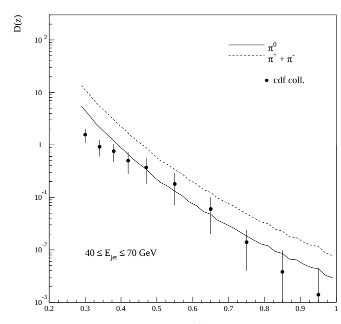

Figure 6: jet fragmentation function, into π^0 and $(\pi^+ + \pi^-)$. The experimental points refer to charged hadrons and are from CDF

4 Conclusions

In this talk I reviewed the results on some recent NLO sets of parton fragmentation functions into light mesons. The possibilities to use them to make reliable predictions at different type of machines has been briefly shown.

5 Acknowledgement

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